Nutritive Value of Chicory and English Plantain Forage

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ABSTRACT

Forage production in midsummer is a challenge for graziers in the northeastern USA. Domesticated cultivars of chicory (*Cichorium intybus* L.) and English plantain (*Plantago lanceolata* L.) are available in the USA as perennial herbs for pastures. These species have been touted as having good summer production and relatively high nutritive value. We conducted two field-plot experiments at Rock Springs, PA, during 1997 to 2001 to evaluate the nutritive value of chicory and plantain under clipping. 'Grasslands Puna', 'Lacerta', and 'Forage Feast' chicory and 'Ceres Tonic' and 'Grasslands Lancelot' grazing plantain were sown in field plots in May 1997 and 1999 and harvested multiple times in 1998 (Exp. 1) and 2000 (Exp. 2). Herbage from three harvests in 1998 and two harvests in 2000 was analyzed for in vitro true digestibility (IVTD); neutral detergent fiber (NDF); and the minerals P, K, Ca, Mg, Mn, Cu, B, and Zn. Averaged for cultivars, chicory had 11% higher ($P < 0.05$) IVTD and 6 to 20% lower ($P < 0.05$) NDF than plantain. Concentrations of all minerals, except for Ca, were 17 to 48% higher ($P < 0.05$) in chicory than in plantain. There were few meaningful differences in nutritive value among cultivars within chicory or plantain. Chicory and plantain are of relatively high nutritive value and could enhance the nutritional profile of mixed species pastures. The nutritive value benefits, however, must be balanced against the lack of persistence of chicory and plantain.

Forage-livestock producers in the northeastern USA often face a shortage of forage on pasture during the mid- to late-summer. Cool-season grasses in the Northeast are most productive in the spring and fall. Producers would like productive and nutritious forage crops for the summer period. Grasslands Puna chicory is an alternative forage introduced from New Zealand (Rumball, 1986). North American research indicates that chicory persists in mixtures with other cool-season forages and increases late-season herbage production (Belesky et al., 1999; Kunelius and McRae, 1999). Several studies have shown good animal performance on grazed chicory (see Barry, 1998 for a comprehensive survey; Turner et al., 1999). Newer cultivars of chicory are available, but information on their use and nutritive value is limited.

Recently, cultivars of English plantain (buckhorn plantain, narrow leaf plantain, ribwort, ribgrass) have been selected for grazing in New Zealand (Stewart, 1996; Rumball et al., 1997). Plantain commonly occurs as an occasional weed in temperate pastures (Bassett, 1973) and has been described as a palatable pasture plant (Ivins, 1952; Foster, 1988). The nutritive value of plantain is relatively unknown. We have investigated the seedling development and establishment of plantain and found that it establishes easily from seed (Sanderson and Elwinger, 2000a, b). Plantain also contains a number of biologically active compounds, such as the iridoid glycosides acubin and catapol, which have chemical defense properties in the plant (El-Niggar and Beal, 1980; Bowers and Stamp, 1992). Plantain and chicory reportedly have medicinal properties in livestock but the research is not conclusive (Knight et al., 1996; Gustine et al., 2001; Marley et al., 2002).

In the northeastern USA, producers frequently establish and manage complex pasture plant communities (Sanderson et al., 2001). New Zealand research indicated that complex mixtures of cool-season grasses, legumes, and pasture herbs including chicory and plantain yielded more dry matter under sheep grazing than mixtures of perennial ryegrass (*Lolium perenne* L.)–white clover (*Trifolium repens* L.) (Ruz-Jerez et al., 1991; Daly et al., 1996). Greater forage growth during the summer, contributed mainly by the forb component (mostly chicory), improved total seasonal production. Trials with several mixtures of forbs, grasses, and white clover under low-input management indicated that plantain competed well with grasses (Fisher et al., 1996). The inclusion of a summer-active forb in mixtures may improve the nutritive value of mid- and late-season forage on mixed-species pastures (Belesky et al., 1999, 2000).

Mineral concentrations in broadleaf plants, such as chicory and plantain, have been reported to be higher than those of grasses and other forages (Thomas et al., 1952; Belesky et al., 2001). Barry (1998) listed higher concentrations of Ca, Na, K, and Mg in chicory compared with perennial ryegrass. The relatively high concentrations of minerals in chicory and plantain may improve the nutrition of grazing animals.

We have conducted several studies on the establishment, production, and persistence of chicory and plantain under clipping and grazing (Sanderson and Elwinger, 2000a, b; Sanderson et al., 2002; Labreveux et al., 2001). Our objective in this study was to determine the nutritive value of chicory and plantain.

MATERIALS AND METHODS

Two field studies were conducted at the Russell E. Larson Agricultural Research Center near Rock Springs, PA. Soil at the site was a Hagerstown silt loam (fine, mixed, semiactive, mesic Typic Hapludalfs). Weather data were obtained from monitoring stations within 1 km of the experimental site.

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Abbreviations: CP, crude protein; IVTD, in vitro true digestibility; NDF, neutral detergent fiber.

Experiment 1

Tonic and Lancelot plantain and Puna, Forage Feast, and Lacerta chicory were seeded with a plot drill in 3.6- by 6.1-m plots on 16 May 1997 in a clean tilled seedbed. Plantain was seeded at 11 kg ha^{-1} and chicory at 4.5 kg ha^{-1}. Lacerta did not establish and was dropped from the experiment. Soil tests in 1997 indicated a pH of 6.3, 59 kg ha^{-1} of available P, and 220 kg ha^{-1} of available K in the surface 15 cm. Plots were fertilized with 27 kg P and 72 kg K ha^{-1} in October 1997 and April 1999. Fertilizer N was applied at 56 kg ha^{-1} in June and July of 1998 and 1999.

The plots were divided lengthwise. One-half was harvested every 3 wk and the other half every 5 wk during May to October of 1998. At each harvest, a 0.5- by 4.6-m strip was cut to a 7-cm height with a rotary mower equipped with a collection bag. The entire sample was dried at 55°C for 48 h to determine forage dry matter yield (reported separately, Sanderson et al., 2002). Plots were rated at each harvest for the percentage of plants that were bolted (chicory) or exhibited flower stalks (plantain). The design of the experiment was a split-plot arrangement of treatments in a randomized complete block with five blocks (replicates). Whole plots were the forage entries and subplots were the harvest intervals.

Experiment 2

A second field study was planted on 28 April 1999 with the same species and cultivars used in 1997. The field site was adjacent to the 1997 planting. Plot size was 1.8 by 4.6m and cultural methods were the same as for the 1997 planting. Soil tests in 1999 indicated a pH of 6.1, 87 kg ha^{-1} of available P, and 120 kg ha^{-1} of available K. Limestone was applied at 4.5 Mg ha^{-1} in April 2000. Fertilizer N was applied at 56 kg ha^{-1} in April, June, and July of 2000. Forage dry matter yield was measured every 4 wk during May to September 2000 (reported separately, Sanderson et al., 2002). Harvest and sample processing procedures were the same as for Experiment 1 except that the mowed strip size was 0.5 by 4 m. Plots were rated at each harvest for the percentage of plants that were bolted (chicory) or had flower stalks (plantain). The experimental design was a randomized complete block with five blocks (replicates).

Nutritive Value Analysis

Plantain did not survive into 1999 or 2001 for Exp. 1 and 2, respectively, and chicory stands were also reduced in those years (Sanderson et al., 2002). Therefore, we analyzed forage from selected harvests in 1998 and 2000 to compare a complete data set of chicory and plantain cultivars. Forage from the 19 May, 30 June, and 2 September harvests of 1998 and the 16 May and 5 September harvests of 2000 was first ground to pass a 2-mm screen in a shear mill and then ground to pass a 1-mm screen in an impact mill. Ground samples were analyzed for NDF and CP (N $\times$ 6.25) via near infrared reflectance spectroscopy by the Crop Quality Laboratory at Penn State University. Calibration statistics for CP were: standard error of cross validation, 12.7; 1-VR, 0.95; standard error of calibration, 11.8; R^2, 0.95. Calibration statistics for NDF were standard error of cross validation, 35; 1-VR, 0.90; standard error of calibration, 27.8; R^2, 0.93. Where, $1 - \text{VR} = 1 -$ variance ratio achieved in cross validation and R^2 = coefficient of determination in modified partial least squares regression. Calibration samples (100) were analyzed for NDF via the Ankom bag method (Ankom 200, Ankom Technology, Fairport, NY.) and N via the Dumas combustion method (AOAC, 1990). Samples were analyzed for the minerals P, K, Ca, Mg, Mn, B, Cu, and Zn via wet chemistry methods (Dahlquist and Knoll, 1978) by the Agricultural Analytical Laboratory at Penn State University. Digestibility (48 h in vitro true digestibility, IVTD; Van Soest and Robertson, 1980) analyses were conducted via wet chemistry methods by a commercial laboratory (Dairy One, Ithaca, NY).

Separate analyses of variance were conducted on the bolting and nutritive value data for each date in both experiments. Planned comparisons were used to compare treatment means. The comparisons for Exp. 1 were (i) the average of chicorys vs. the average of plantains, (ii) Lancelot plantain vs. Tonic plantain, and (iii) Puna chicory vs. Forage Feast chicory. The comparisons for Exp. 2 were (i) the average of chicorys vs. the average of plantains, (ii) Lancelot plantain vs. Tonic plantain, (iii) Puna chicory vs. other chicorys, and (iv) Forage Feast chicory vs. Lacerta chicory.

RESULTS AND DISCUSSION

Weather

The spring of 1998 was warm and wet compared with the 30-yr average temperature and rainfall (Table 1). Rainfall was more than 50% above average for April to June 1998. Summer of 1998 was near normal in temperature and 30% below the 30-yr average rainfall. The temperature was slightly below normal for most of the growing season of 2000 and rainfall was about 22% below the long-term average.

In Vitro Digestibility, Fiber, and Crude Protein Concentrations

More-frequent harvests seemed to improve nutritive value. Herbage from the 5-wk harvest interval in 1998 was generally one to two percentage units lower in IVTD, NDF, and CP than herbage from the 3-wk harvest interval (data not shown). There was no interaction, however, between species and harvest interval for IVTD, therefore means of the two harvest intervals are presented (Table 2). Chicory was about 11% higher ($P < 0.05$) in IVTD than plantain at each sampling date in both experiments. There were no significant

Table 1. Air temperature and monthly rainfall at Rock Springs, PA, during the growing seasons of 1998 and 2000.

	Average monthly air temperature			Rainfall		
Month	1998	2000	30-yr average	1998	2000	30-yr average
	°C			mm		
April	10.0	8.6	8.7	172	74	74
May	17.0	15.9	14.8	116	62	92
June	18.5	19.7	19.5	131	97	102
July	20.7	18.9	21.8	89	53	92
Aug.	20.9	19.1	20.9	71	74	81
Sept.	18.6	15.1	16.8	44	48	82

Table 2. Nutritive value of chicory and plantain grown in two field experiments at Rock Springs, PA. Data for Exp. 1 are averages of 3- and 5-wk cutting intervals and five replicates. The data for Exp. 2 are averages of five replicates.

	Exp. 1 (1998)			Exp. 2 (2000)	
Entry	May	June	September	May	September
	dry matter (g kg^{-1})				
	In vitro true digestibility				
Forage Feast chicory	863	807	845	903	813
Puna chicory	886	821	875	905	820
Lacerta chicory				891	808
Lancelot plantain	738	713	803	780	770
Tonic plantain	799	724	777	783	768
Pooled SE	18.0	19.9	13.0	13.3	13.4
Contrasts					
Chicory vs. plantain	**	**	**	**	**
Puna vs. other chicory	NS	NS	NS	NS	NS
Lancelot vs. Tonic	*	NS	NS	NS	NS
Feast vs. Lacerta				NS	NS
	Neutral detergent fiber				
Forage Feast chicory	429	455	410	314	442
Puna chicory	507	435	381	311	419
Lacerta chicory				323	445
Lancelot plantain	527	502	514	395	475
Tonic plantain	467	476	451	374	471
Pooled SE	30.8	5.9	6.6	4.8	11.5
Contrasts					
Chicory vs. plantain	NS	**	**	**	**
Puna vs. other chicory	NS	%	**	NS	NS
Lancelot vs. Tonic	NS	%	**	**	NS
Forage Feast vs. Lacerta				NS	NS
	Crude Protein				
Forage Feast chicory	175	195	161	151	127
Puna chicory	200	181	152	135	131
Lacerta chicory				123	104
Lancelot plantain	150	173	118	114	105
Tonic plantain	185	179	141	134	108
Pooled SE	12.5	2.8	3.7	2.4	7.0
Contrasts					
Chicory vs. plantain	NS	**	**	**	*
Puna vs. other chicory	NS	**	NS	NS	NS
Lancelot vs. Tonic	NS	NS	**	**	NS
Forage Feast vs. Lacerta				**	*

* Significant at $P < 0.05$.
** Significant at $P < 0.01$.
NS, not significant.

differences between cultivars within chicory for IVTD in either experiment. Tonic plantain had a greater IVTD ($P < 0.05$) than Lancelot at the May harvest in 1998; however, plantain cultivars did not differ ($P > 0.05$) in IVTD at other harvests. Turner et al. (1999) reported in vitro organic matter digestibility of 555 g kg^{-1} for Puna chicory compared with 564 g kg^{-1} for alfalfa (*Medicago sativa* L.) in West Virgina. The IVTD of plantain in our experiments averaged 765 g kg^{-1}. Derrick et al. (1993) reported IVTD values of 698 to 913 g kg^{-1} for a naturalized ecotype of plantain in the United Kingdom. We could not find any reports where the nutritive value of chicory and plantain had been compared directly.

Neutral detergent fiber concentrations were 6 to 20% lower ($P < 0.01$) in chicory than in plantain during Exp. 1 and 2 (Table 2). Averaged for cultivars, chicory had NDF concentrations of 412 g kg^{-1} vs. 465 g kg^{-1} for plantain. Significant cultivar differences in NDF were observed within chicory and plantain at some harvests. Puna chicory had a lower ($P < 0.05$) NDF concentration than Forage Feast in Exp. 1; however, the differences among chicory cultivars were not significant in Exp. 2. Tonic plantain was lower than Lancelot plantain in NDF during June and September of 1998 and May of 2000. Turner et al. (1999) reported NDF levels of 470 g kg^{-1} for Puna chicory vs. 534 g kg^{-1} for alfalfa in a grazed field plot experiment in West Virginia. Derrick et al. (1993) reported NDF concentrations of 282 to 455 g kg^{-1} for a naturalized ecotype of plantain, somewhat lower than concentrations in our study. Wilman and Riley (1993) reported NDF levels of 250 g kg^{-1} for plantain compared with 229 g kg^{-1} for white clover and 397 g kg^{-1} for perennial ryegrass in a greenhouse pot study.

Chicory had higher ($P < 0.05$) CP than plantain at most harvests in both experiments (Table 2). There were only a few instances when cultivars within chicory and plantain differed in CP. Forage Feast chicory had 20% higher CP than Lacerta chicory in Experiment 2 and slightly higher CP than Puna chicory in June 1998. Crude protein levels of chicory in our study were similar to those reported by Volesky (1996) for Puna chicory grazed in different rotational stocking schemes.

Cultivars of chicory and plantain differed in the degree of bolting at each harvest date in both experiments.

Table 3. Visual assessment of bolting in chicory and flower stalk formation in plantain grown in two field experiments at Rock Springs, PA.

	Exp. 1 (1998)					Exp. 2 (2000)	
		June		September			
Entry	May	3 wk	5 wk	3 wk	5 wk	May	September
	Bolting or flower stalk formation (%)						
Forage Feast chicory	3	19	13	3	13	1	1
Puna chicory	43	33	32	2	17	21	1
Lacerta chicory						10	5
Lancelot plantain	70	22	45	1	6	79	7
Tonic plantain	17	52	39	1	9	33	7
Pooled SE	4.0	5.9	5.4	2.4	2.1	3.8	1.5
Contrasts							
Chicory vs. plantain	**	*	**	NS	**	**	**
Puna vs. other chicory	**	*	**	NS	NS	**	NS
Lancelot vs. Tonic	**	**	NS	NS	NS	**	NS
Forage Feast vs. Lacerta						NS	*

* Significant at $P < 0.05$.
** Significant at $P < 0.01$.
NS, not significant.

Forage Feast chicory generally bolted less than Puna or Lacerta chicory (Table 3). The flower stalks of chicory have a lower digestibility and greater fiber concentration than leaves (Barry, 1998). With less bolting we might have expected lower NDF concentrations and perhaps a greater IVTD in Forage Feast than other cultivars; however, this was not the case.

There was a great degree of flower stalk formation in the plantain cultivars in both experiments (Table 3), which might account for some of the difference in nutritive value between plantain and chicory (Table 2). Animal feeding trials showed that flower stalks reduced intake and digestibility of plantain fed to sheep (*Ovis aries*) and that the cell wall digestibility of flower stalks from plantain was very low (Derrick et al., 1993). Plantain leaves have prominent parallel veins, which are protected by bundles of schlerenchyma fibers on each side. Plantain leaves also have a layer of collenchyma cells beneath a relatively thick-walled epidermis (Soekarjo, 1992). The schlerenchyma fibers, collenchmyma cells, and thick epidermis may account for the higher NDF levels in plantain compared with chicory.

We evaluated the chicory and plantain cultivars in monocultures; however, these species frequently occur in mixed-species swards (Belesky et al., 1999). There is some evidence that mixtures of chicory with orchardgrass (*Dactylis glomerata* L.) enhanced in vitro digestion kinetics (Turner et al., 1999); however, grazing studies showed no difference in weight gain of lambs grazed on orchardgrass monocultures or a mixed orchardgrass-chicory sward. Although we showed little different among chicory cultivars in NDF or IVTD, recent research with the same chicory cultivars suggests that sheep and white-tail deer (*Odocoileus virginianus*) prefer some chicory cultivars over others (Foster et al., 2002). In a free-foraging situation, deer avoided Forage Feast and selected Lacerta chicory. In cafeteria trials, sheep also avoided Forage Feast. Thus, other plant traits (perhaps secondary metabolites) may affect animal performance on chicory (Foster et al., 2002).

Mineral Concentrations

Herbage from the 5-wk harvest interval in Exp. 1 was slightly lower in mineral concentrations than was herbage from the 3-wk harvest interval (data not shown). For example, P was 4.7 and 4.3 g kg^{-1} in 3- and 5-wk herbage, respectively, and K was 33 and 32 g kg^{-1} (averaged for cultivars and harvest dates; data not shown). There were no important interactions, however, between species and harvest interval; therefore, means of the two harvest intervals are presented (Table 4 and 5). Plantain herbage had lower ($P < 0.01$) concentrations of nearly all mineral elements than chicory in both experiments. Plantain was 17% lower in P and about 30% lower in K, Mg, Cu, B, and Zn than was chicory. The largest disparity between species was in Mn concentration; plantain had 48% less Mn than chicory.

Forage Feast chicory had greater concentrations of P and Mg but lower K than Lacerta chicory in Experiment 2 (Table 4). Lancelot plantain had greater Ca and Zn concentrations than Tonic plantain at nearly all harvests in both experiments; however, cultivar differences in other minerals were inconsistent (Tables 4 and 5). Puna chicory had lower Cu concentrations than other chicory cultivars at most harvests.

Mineral concentrations in Puna chicory were generally similar to those reported by Jung et al. (1996) and Belesky et al. (2001) (Table 6). Jung et al. (1996) compared the mineral concentrations of Puna chicory to 'Pennlate' orchardgrass growing at Rock Springs on the same soil type as our experiments. We have summarized the concentrations from the "moderate" management system (four cuts, 200 kg ha^{-1} N) of that study in Table 6 for comparison. We found slightly higher P, K, and Cu concentrations than Jung et al. (1996). Concentrations of Ca, Mg, Cu, B, and Zn in chicory and plantain in our study were all greater than for Pennlate orchardgrass reported by Jung et al. (1996). The mineral concentrations of plantain in our study were generally similar to those reported by Wilman and Riley (1993) who compared several different naturalized ecotypes of

Table 4. Macro-mineral concentrations of chicory and plantain grown in two field experiments at Rock Springs, PA. The data for Exp. 1 are averages of 3- and 5-wk cutting intervals and five replicates. The data for Exp. 2 are averages of five replicates.

Entry	Exp. 1 (1998) May	Exp. 1 (1998) June	Exp. 1 (1998) September	Exp. 2 (2000) May	Exp. 2 (2000) September
	dry matter (g kg^{-1})				
	Phosphorus				
Forage Feast chicory	4.7	4.8	5.0	4.3	5.0
Puna chicory	5.0	4.7	5.5	3.5	5.2
Lacerta chicory				3.5	4.2
Lancelot plantain	4.1	3.7	3.9	2.9	3.8
Tonic plantain	4.5	4.2	4.3	3.0	3.7
Pooled SE	0.35	0.11	0.16	0.07	0.14
Contrasts					
Chicory vs. plantain	NS	**	**	**	**
Puna vs. other chicory	NS	NS	*	**	**
Lancelot vs. Tonic	NS	**	NS	NS	NS
Forage Feast vs. Lacerta				**	**
	Potassium				
Forage Feast chicory	40	36	31	31	25
Puna chicory	59	34	35	36	32
Lacerta chicory				35	27
Lancelot plantain	33	22	21	25	21
Tonic plantain	34	25	23	19	19
Pooled SE	3.3	0.7	1.2	1.1	1.2
Contrasts					
Chicory vs. plantain	**	**	**	**	**
Puna vs. other chicory	**	NS	NS	*	**
Lancelot vs. Tonic	NS	*	NS	**	NS
Forage Feast vs. Lacerta				**	NS
	Calcium				
Forage Feast chicory	15	18	18	16	25
Puna chicory	19	18	19	15	22
Lacerta chicory				19	18
Lancelot plantain	18	19	8	17	14
Tonic plantain	23	23	19	27	20
Pooled SE	1.2	0.5	0.8	0.6	1.4
Contrasts					
Chicory vs. plantain	*	**	**	**	**
Puna vs. other chicory	*	NS	NS	**	NS
Lancelot vs. Tonic	**	**	**	**	**
Forage Feast vs. Lacerta				**	**
	Magnesium				
Forage Feast chicory	4.8	5.1	4.7	4.8	5.0
Puna chicory	5.6	4.8	5.0	4.3	4.4
Lacerta chicory				4.2	4.0
Lancelot plantain	3.9	4.0	3.4	3.2	2.9
Tonic plantain	3.7	3.7	3.4	2.8	2.6
Pooled SE	0.45	0.16	0.09	0.17	0.20
Contrasts					
Chicory vs. plantain	**	**	**	**	**
Puna vs. other chicory	NS	NS	*	NS	NS
Lancelot vs. Tonic	NS	NS	NS	NS	NS
Forage Feast vs. Lacerta				*	**

* Significant at $P < 0.05$.
** Significant at $P < 0.01$.
NS, not significant.

broadleaf plants with perennial ryegrass and white clover in a greenhouse pot study.

Mineral concentrations of plantain and chicory in our study were comparable to mineral concentrations listed by the NRC (1989, 1996) for late vegetative alfalfa and white clover (Table 6) and generally met or exceeded the mineral nutrient levels recommended by the National Research Council (1989, 1996) for lactating dairy cattle (*Bos taurus*) and growing beef cattle (Table 6).

The levels of K in chicory and plantain (Table 4) could be a concern in maintaining the cation–anion balance of grazed lactating dairy cows. High levels of K in green pasture often leads to high dietary cation–anion balance [(Na + K)–(Cl + S)] in grazing livestock (Judson and McFarlane, 1998). The high cation-anion balance causes a mild metabolic alkalosis, which reduces Ca mobilization from bone and availability of dietary Ca potentially leading to milk fever. High levels of dietary K may also inhibit Mg absorption from the rumen.

The relatively high concentration of Mg and Ca in chicory and plantain (Table 4) may reduce the risk of grass tetany (hypomagnesemia) on mixed species pastures. The risk for grass tetany is very high on lush pastures with less than 2.0 g kg^{-1} Mg, 3 g kg^{-1}Ca, 1.5 g kg^{-1} Na, and K at greater than 30 g kg^{-1} of dry matter (Mayland and Grunes, 1979) along with N concentra-

Table 5. Micromineral concentrations of chicory and plantain grown in two field experiments at Rock Springs, PA. The data for Exp. 1 are averages of 3- and 5-wk cutting intervals and five replicates. The data for Exp. 2 are averages of five replicates.

	Exp. 1 (1998)			Exp. 2 (2000)	
Entry	May	June	September	May	September
	dry matter (g kg^{-1})				
	Boron				
Forage Feast chicory	32	34	36	35	45
Puna chicory	46	34	37	39	39
Lacerta chicory				36	31
Lancelot plantain	32	25	13	28	20
Tonic plantain	31	27	22	28	21
Pooled SE	2.1	0.6	1.0	1.2	1.4
Contrasts					
Chicory vs. plantain	**	**	**	**	**
Puna vs. others	**	NS	NS	*	NS
Lancelot vs. Tonic	NS	*	**	NS	NS
Forage Feast vs. Lacerta				NS	**
	Copper				
Forage Feast chicory	75	44	23	20	31
Puna chicory	29	44	19	16	26
Lacerta chicory				18	28
Lancelot plantain	19	29	15	11	19
Tonic plantain	29	31	18	16	21
Pooled SE	15.0	6.7	0.9	1.0	1.4
Contrasts					
Chicory vs. plantain	NS	*	**	**	**
Puna vs. other chicory	*	NS	*	**	*
Lancelot vs. Tonic	NS	NS	*	**	NS
Forage Feast vs. Lacerta				NS	NS
	Manganese				
Forage Feast chicory	194	188	136	116	288
Puna chicory	149	158	143	132	271
Lacerta chicory				136	228
Lancelot plantain	54	98	78	64	128
Tonic plantain	87	80	74	151	128
Pooled SE	31.3	9.9	9.9	5.8	17.0
Contrasts					
Chicory vs. plantain	**	**	**	**	**
Puna vs. other chicory	NS	*	NS	NS	NS
Lancelot vs. Tonic	NS	NS	NS	**	NS
Forage Feast vs. Lacerta				*	*
	Zinc				
Forage Feast chicory	44	44	44	38	57
Puna chicory	38	46	52	37	64
Lacerta chicory				32	57
Lancelot plantain	23	34	30	19	30
Tonic plantain	31	37	38	26	37
Pooled SE	5.7	1.7	1.5	1.0	2.2
Contrasts					
Chicory vs. plantain	*	**	**	**	**
Puna vs. others	NS	NS	**	NS	*
Lancelot vs. Tonic	NS	**	**	**	*
Forage Feast vs. Lacerta					NS

* Significant at $P < 0.05$.
** Significant at $P < 0.01$.
NS, not significant.

tions greater than 40 g kg^{-1}. Concentrations of Mg, Ca, and Na were all less than these thresholds for chicory and plantain in our study. Potassium concentrations were very high for chicory in a few instances, but generally were around 20 to 30 g kg^{-1}. In general, however, our results for chicory confirm the conclusions of Belesky et al. (2001) that mineral imbalances for livestock grazing chicory would not be a concern. These concerns would probably be minimal for plantain as well.

CONCLUSIONS

Inclusion of herbs, such as chicory or plantain, in pastures may enhance the nutritional profile of the grazed forage and may be equivalent in nutritive value to forage grasses and legumes. Our earlier research documented yields of 5000 to 8000 kg ha^{-1} for chicory and 5000 to 7500 kg ha^{-1} for plantain. Chicory cultivars varied in persistence, however, with Lacerta suffering an 80% loss of plants compared with 20 to 60% losses for Forage Feast and Puna during 3 yr (Sanderson et al., 2002). Plantain suffered a nearly complete loss of plants during the second winter after establishment. Thus, any potential nutritional benefits of chicory and plantain must be balanced against the short-term persistence of chicory and the lack of persistence in plantain in our environment.

Table 6. Mineral concentrations of chicory and plantain in this study compared with other data sources and with NRC nutrient recommendations for cattle.

Element	This study		Other studies					NRC listed concentrations and diet nutrient density recommendations for dairy and beef cattle				
	Plantain	Chicory	Plantain†	Plantain‡	Puna chicory§	Puna chicory¶	Orchard grass§	Orchard grass	Alfalfa	White clover	Dairy#	Beef#
	dry matter (g kg^{-1})											
P	3.9	4.7	4.5	3.2	4.6	3.8	3.3	3.4	3.3	3.3	3.8	2.4
K	25	36	44	27	21	26.9	27.3	29.1	25.1	24.4	9.0	6.0
Ca	19	18	20	17	15	14.4	5.2	2.7	15	14.5	6.0	3.8
Mg	3.5	4.8	2.4	6	5.4	5.0	2.7	1.1	2.1	4.7	2.0	1.2
Mn	89	170		35		104	112	157	47	123	40	40
Cu	22	32		11	33	10	7.2	19	11.4	9.4	10	10
B	25	33			19	36	6.5					
Zn	31	45			63	32	24	40	37	17	40	30

† Wilman and Riley (1993).
‡ Thomas et al. (1952).
§ Jung et al. (1996).
¶ Belesky et al. (1999).
# National Research Council (1989, 1996).

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